JAPANESE PATENT PUBLICATION (A)

(54) HOT ROLLING STEEL SHEET WITH HIGH STRENGTH, EXCELLENT IN BORING PROPERTY AND DUCTILITY, AND ITS PRODUCTION

(57) [ABSTRACT]

[PROBLEM] To provide a high strength hot rolled steel sheet having a 590N/mm^2 or higher tensile strength and having an excellent hole expansibility and ductility.

[MEANS FOR SOLUTION] Containing, by wt%, C: 0.01% to 0.20%, Si: 0.3% to 1.5%, Mn: 0.5% to 2.5%, P: 0.10% or less, S: 0.009% or less, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, and further controlling the oxides to make the steel structure containing MgO having a

particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 containing MgO in an amount of 1.0×10^3 to 1.0×10^7 per square mm mainly a ferrite structure and the remainder a bainite structure.

[CLAIMS]

[Claim 1] High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% to 0.20%,

Si: 0.05% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.10% or less%,

S: 0.009% or less,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07% and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[Claim 2] High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% to 0.20%,

Si: 0.3% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.10% or less,

S: 0.009% or less,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07%, and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[Claim 3] High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% to 0.20%,

Si: 0.3% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.10% or less,

S: 0.009% or less,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07%, and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities,

further containing one or both of

Ca: 0.0005% to 0.0100% and

REM elements in total: 0.0005% to 0.0100%,

having a balance of iron and unavoidable impurities, and

making a steel structure containing MgO having a particle

size of 0.005 μm to 5.0 μm or or composite oxides of one or

more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO in an

amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly

a ferrite structure and making the remainder a bainite

structure.

[Claim 4] High strength hot rolled steel sheet excellent in

hole expansibility and ductility characterized by

containing, by wt%,

C: 0.01% to 0.20%,

Si: 0.3% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.10% or less,

S: 0.009% or less,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07%, and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities,

further containing one or both of

Ca: 0.0005% to 0.0100% and

REM elements in total: 0.0005% to 0.0100%,

having a balance of iron and unavoidable impurities, and making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[Claim 5] A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in claim 1 or claim 2 or claim 3 or claim 4 by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed, and taking up the sheet at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[Claim 6] A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in claim 1 or claim 2 or claim 3 or claim 4 by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed down to 650°C to 700°C, air cooling at that temperature for 15 seconds or less, then again cooling and coiling at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[Claim 7] A method of production of high strength hot rolled steel sheet excellent in hole expansibility and

ductility characterized by adding Si and Mn, then adding
Ti, then adding Mg and Al in the steel described in claim 1
or claim 2 or claim 3 or claim 4 and at the step of
adjusting the ingredients at a melting stage of the method
of production of steel described in claim 5 or claim 6.
[Claim 8] A method of production of high strength hot
rolled steel sheet excellent in hole expansibility and
ductility as set forth in claim 5 or claim 6 or claim 7
characterized by using an Mg alloy comprised of one or more
of Si, Ni, Cu, Al, and REM (rare earth metal) as a dilute
solvent metal of Mg.
[Claim 9] A method of production of high strength hot
rolled steel sheet excellent in hole expansibility and
ductility as set forth in claim 8 characterized in that an
Mg concentration in the Mg alloy is 1% to less than 10%.
[Claim 10] A high strength hot rolled steel sheet excellent
in hole expansibility and ductility as set forth in claims
7 to 9 characterized in that a sum of concentrations of Fe,
Mn, and Cr in the Mg alloy is less than 10% and a method of
production of the same.
[DETAILED DESCRIPTION OF THE INVENTION]
[0001]
[TECHNICAL FIELD OF THE INVENTION] The present invention
mainly covers steel sheet for automobiles used press formed
and relates to high strength hot rolled steel sheet
excellent in hole expansibility and ductility having a
thickness of 1.0 to 6.0 mm or so and a tensile strength of
590N/mm^2 or more and a method of production of the same.
[0002]
[PRIOR ART] In recent years, as a measure to improve the
fuel efficiency of automobiles, chasses are being reduced

in weight. There has also been a growing need for reduction of costs by integral formation of parts. Hot rolled high strength steel sheet excellent in press formability is therefore being developed. In the past, as hot rolled steel sheet for working use, dual phase steel sheet comprised of a ferrite and martensite structure has been known. Dual phase steel sheet is comprised of a composite structure of a soft ferrite phase and a hard martensite phase. Voids form from the interface of the two phases remarkably different in hardness resulting in cracks, so there is a problem in deterioration of the hole expansibility. This is therefore not suitable for applications like chassis parts where a high hole expansibility is required.

[0003] For this reason, Japanese Patent Publication (A) No. 4-88125 and Japanese Patent Publication (A) No. 3-180426 propose methods of production of hot rolled steel sheet excellent in hole expansibility comprised of a structure mainly comprised of bainite. Further, Japanese Patent Publication (A) No. 6-293910 proposes a method of production achieving both hole expansibility and ductility by using a two-stage cooling process so as to control the ferrite ratio. However, due to the orientation toward further reduction of weight of automobiles, the increasing complexity of parts, etc., a further higher hole expansibility is being sought and a higher workability and higher strength unable to be achieved in the above art are being demanded.

[0004]

[PROBLEM TO BE SOLVED BY THE INVENTION] The present invention relates to hot rolled steel sheet of the 590N/mm^2 class or more and attempts to provide high strength hot

41

rolled steel sheet achieving both excellent hole expansibility and ductility.

[0005]

[MEANS FOR SOLVING THE PROBLEMS] To solve the problems of the present invention, various experiments and studies have been performed. As a result, it is well known that the state of cracks in punched holes is important for improvement of the hole expansibility. The inventors engaged in in-depth studies and as a result discovered that by adding Mg, it is possible to make the cracks formed at the cross-section of punched holes finer and more uniform. Further, by making oxides present in the steel sheet and composite precipitates of (Nb, Ti)N having these as nuclei uniformly and finely disperse and precipitate, it is believed that it is possible to cause the formation of fine voids at the time of punching and thereby ease the concentration of stress and believed possible to suppress the occurrence of coarse cracks and improve the hole expansibility. Due to this, they came up with the invention. Up to now, as proposals utilizing oxides obtained by addition of Mg, for example, the proposal of Japanese Patent Publication (A) No. 11-323488 relating to improvement of in-plane anisotropy is directed to use of Mg oxides for suppression of the preferential nucleation and growth in the planar direction at the time of recrystallization. The proposal of Japanese Patent Publication (A) No. 11-236645 relating to the toughness of the weld zone aims at using Mg composite oxides to suppress the growth of γ grains of the HAZ part at the time of superlarge heat input welding. These utilize the pinning effect by fine oxides. Unlike the utilization of the fine

42

voids formed by inclusions at the time of punching of the present invention, it is not certain that the hole expansibility is improved at steel sheet aimed at these. The gist of the present invention is as follows.

[0006] 1) High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.05% to 1.5%, Mn: 0.5% to 2.5%, P: 0.10% or less%, S: 0.009% or less, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07% and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0007] 2) High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.3% to 1.5%, Mn: 0.5% to 2.5%, P: 0.10% or less, S: 0.009% or less, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm

43

mainly a ferrite structure and making the remainder a bainite structure.

[0008] 3) High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.3% to 1.5%, Mn: 0.5% to 2.5%, P: 0.10% or less, S: 0.009% or less, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, further containing one or both of Ca: 0.0005% to 0.0100% and REM elements in total: 0.0005% to 0.0100%, having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0009] 4) High strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.3% to 1.5%, Mn: 0.5% to 2.5%, P: 0.10% or less, S: 0.009% or less, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, further containing one or both of Ca: 0.0005% to 0.0100% and REM elements in total: 0.0005% to 0.0100%, having a balance of iron and unavoidable impurities, and making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO and

44

precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0010] 5) A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in 1) or 2) or 3) or 4) by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed, and taking up the sheet at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[0011] 6) A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in 1) or 2) or 3) or 4) by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed down to 650°C to 700°C, air cooling at that temperature for 15 seconds or less, then again cooling and coiling at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[0012] 7) A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by adding Si and Mn, then adding Ti, then adding Mg and Al in the steel described in 1) or 2) or 3) or 4) and at the step of adjusting the ingredients at a melting stage of the method of production of steel described in 5) or 6).

45

0013] 8) A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in 5) or 6) or 7) characterized by using an Mg alloy comprised of one or more of Si, Ni, Cu, Al, and REM (rare earth metal) as a dilute solvent metal of Mg.

[0014] 9) A method of production of high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in 8) characterized in that an Mg concentration in the Mg alloy is 1% to less than 10%.

[0015] 10) A high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in 7) to 9) characterized in that a sum of concentrations of Fe, Mn, and Cr in the Mg alloy is less than 10% and a method of production of the same.

[0016]

[EMBODIMENTS OF THE INVENTION] The present invention suppresses coarse cracks at the punched holes for improvement of the hole expansibility. For this, it adds Mg, causes oxides to uniformly and finely precipitate, and thereby suppresses the occurrence of coarse cracks at the time of punching and improves the hole expansibility. Below, the individual constituent requirements of the present invention will be explained in detail.

[0017] First, the reasons for limitation of the ingredients of the present invention will be explained. C is an element having an effect on the workability of the steel. If the content becomes greater, the workability is degraded. In particular, if over 0.20%, carbides (pearlite and cementite) harmful to the hole expansibility are formed, so the amount is 0.20% or less. However, preferably, 0.15% or less is desirable. Further, from the viewpoint of securing

46

the strength, 0.01% or more is necessary.

[0018] Si is an element important for suppressing the formation of harmful carbides and obtaining a composite structure of mainly ferrite structure and a balance of bainite. Further, due to the action of Si, there is also the action of achieving both strength and ductility. To obtain such an action, addition of 0.3% or more is necessary. However, if the amount of addition increases, the chemical convertibility falls and also the point weldability deteriorates, so 1.5% is made the upper limit.

[0019] Mn is an element necessary for securing the strength. Addition of a minimum of 0.50% is necessary. However, if adding a large amount, microsegregation and macrosegregation easily occur. These cause deterioration of the hole expansibility. Due to this, 2.50% is made the upper limit.

[0020] P is an element raising the strength of the steel sheet, but if the amount of addition is high, causes deterioration of the weldability, workability, and toughness. Due to this, the amount is made 0.10% or less, preferably 0.03% or less.

[0021] S forms MnS and other nonmetallic inclusions and degrades the ductility and hole expansibility, so is preferably not present in the steel. The smaller the amount of addition the better, so the amount is made 0.009% or less. However, if 0.005% or less, this effect remarkably appears, so 0.005% or less is preferable.

[0022] N is preferably small in amount to secure the workability. If over 0.010%, the workability deteriorates, so the amount is made 0.010% or less. 0.005% or less is preferable.

47

[0023] Mg is one of the most important additive elements in the present invention. Mg, upon addition, bonds with oxygen to form oxides, but it was discovered that by making the MgO or composite oxides of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO formed at this time finer, the individual oxide particles are smaller in size and the particles are more uniformly dispersed compared with conventional steel in which Mg is not added. Finely dispersed in the steel, these oxides, while not certain, are believed to be effective for formation of fine voids at the time of punching and suppression of stress concentration so as to suppress the formation of coarse cracks and are believed to be effective for the improvement of hole expansibility. However, if less than 0.0005%, the effect is insufficient. On the other hand, with addition of over 0.01%, not only is improvement relative to the amount of addition saturated, but also conversely the cleanliness of the steel is degraded and the hole expansibility and ductility are degraded, so the upper limit is made 0.01%.

[0024] Al is one of the most important additive elements in the present invention. Al easily forms $MgAl_2O_4$ composite oxides having a spinel structure when Mg is added. $MgAl_2O_4$ composite oxides are a form of the finest oxides among composite oxides of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO and are believed to be effective for making the state of dispersion of the oxides more uniform and finer. For this reason, at the time of punching, fine voids are formed. These suppress the stress concentration and thereby are believed to have the effect of suppressing the formation of coarse cracks and are believed to have the effect of improvement of the hole expansibility. Due to this, 0.002%

48

or more is added. However, if the amount of addition increases, the effect of addition of Mg is impaired, so the amount is made 0.07% or less. In particular, to raise the ratio of the MgAl composite oxides among the composite oxides in the oxides and efficiently achieve greater fineness of oxides, the amount of addition is preferably 0.02% to 0.07%.

[0025] Ti and Nb are some of the most important additive elements in the present invention. Ti and Nb precipitate about nuclei of finely and uniformly precipitating oxides, in particular composite oxides mainly comprised of small MgO or $MgAl_2O_4$. By precipitating on these oxides, they act to increase the size of the precipitates and thereby assist the formation of fine voids of MgO or $MgAl_2O_4$. Further, this is also effective for increasing the strength. To effectively bring out these effects, addition of at least 0.003% of both Nb and Ti is necessary. Addition of 0.01% or more is preferable. However, if addition of these becomes excessive, the precipitation strengthening causes the ductility to deteriorate, so the upper limit of Ti is made 0.25% or less and of Nb is made 0.04% or less. These elements are effective even if added alone and are effective even if added compositely.

[0026] Ca controls the shape of sulfide-based inclusions and is effective for improvement of the hole expansibility. To effectively bring this out, addition of 0.0005% or more is necessary. On the other hand, addition of a large amount conversely degrades the cleanliness of the steel, so impairs the hole expansibility and ductility. Due to this, the upper limit is made 0.0100%. REM elements have similar effects to Ca. That is, a REM controls the shape of

49

sulfide-based inclusions and is effective for improvement of the hole expansibility. To effectively bring this out, addition of a total of REM elements of 0.0005% or more is necessary. On the other hand, addition of a large amount conversely degrades the cleanliness of the steel, so impairs the hole expansibility and ductility. Further, the production costs are also high, so the upper limit was made 0.0100%.

[0027] As the oxides, MgO or composite oxides of two or more of Al_2O_3, SiO_2, MnO, and Ti_2O_3 including MgO may also be used. The inventors engaged in in-depth studies and as a result learned that among the composite oxides, MgO and $MgAl_2O_4$ are effective in forming fine cracks in a state different from other composite oxides, these are all effects obtained by addition of Mg, and the synergistic effect causes an improvement in the hole expansibility.

[0028] MgO and $MgAl_2O_4$ mainly cause precipitation of (Nb, Ti)N around them and thereby have the effect of forming fine voids. MgO and $MgAl_2O_4$ are believed to contribute to this as nuclei for precipitation uniformly dispersed. On the other hand, fine composite oxides other than MgO and $MgAl_2O_4$ precipitate finely dispersed due to the formation of composite oxides with MgO and have the effect of formation of fine voids as oxides alone without causing precipitation of (Nb, Ti)N around them. In particular, the fine composite oxides other than MgO and $MgAl_2O_4$ are almost all composite oxides mainly comprised of MgO, Al_2O_3, and SiO_2. At this time, the ratio of MgO, Al_2O_3, and SiO_2 oxides in the whole is 90% or more.

[0029] If the particle size of oxides is less than 0.005 μm, there is little precipitation of (Nb, Ti)N around them.

50

On the other hand, it is difficult for this size of oxides to become nuclei for formation of fine cracks without coprecipitation of (Nb, Ti)N. The effect of formation of fine voids becomes difficult to obtain, so the size is made 0.005 μm or more. Conversely, if over 5.0 μm, securing the number of particles is difficult. Further, coarse precipitates invite deterioration in the ductility, so the size is made 5.0 μm or less.

[0030] If the oxides and composite precipitates are small in size, they do not form starting points for fine voids, so cannot exhibit the desired effect. Therefore, the size is made 0.05 μm or more. On the other hand, if over 5.0 μm, securing the number of particles is difficult. These assist the formation of coarse cracks and reduce the hole expansibility, so the size is made 5.0 μm or less.

[0031] If the precipitate density, that is, number, is low, the fine voids formed at the time of punching become insufficient and the effect of suppression of formation of coarse cracks may not be obtained. To obtain this effect, 1.0×10^3 or more per square mm is necessary. On the other hand, if the number becomes large, the effect becomes saturated and conversely the ductility is degraded, so the density is made 1.0×10^7 or less. However, from the balance between the saturation of this effect and the ductility, 1.0×10^6 or less is preferable.

[0032] Further, as the means for improving the hole expansibility, in addition to the properties of the punched hole, improving the local ductility of the base material is effective. To improve the local ductility of the base material, making the structure uniform is effective, but in

single phase steel, at the strength aimed at by the present invention, the deterioration of the ductility is large and the targeted properties cannot be obtained. For this reason, the structure of the steel is made a composite structure of mainly a ferrite structure. However, if the ratio of the ferrite structure is high and the result becomes a single phase steel, a drop in the ductility or strength is caused. Further, when the ratio is low, the effect of the second phase with the low elongation is felt and the ductility falls. For this reason, the ratio of the ferrite structure is preferably 50% to 95%. Further, when the remaining structure is a martensite, coarse cementite, or pearlite structure, cracks form at the interface between the ferrite structure and these structures and the local deformation ability falls. On the other hand, a bainite structure is a structure comprised of a ferrite structure in which fine cementite is dispersed. To prevent a drop in the local ductility of the base material, the structure of the steel is made mainly a ferrite structure and the remainder a bainite structure.

[0033] The state of dispersion of inclusions prescribed in the present invention is for example quantitatively measured by the following method. An extraction replica sample is prepared from any location of the base material steel sheet. This is observed using said transmission electron microscope (TEM) at a power of 5000X to 20000X over an area of at least 5000 μm^2. The number of composite inclusions covered is measured and converted to a number per unit time. At this time, the oxides and the (Nb, Ti)N are identified by analysis of the composition by an energy dispersion type X-ray spectrometer (EDS) attached to the

52

TEM and by analysis of the crystalline structure of an electron beam diffraction image by the TEM. When such identification is bothersome for all composite inclusions measured, for simplification, the following procedure is used. First, the number of inclusions of the size covered is measured for each shape and size by the above guidelines. Among these, 10 or more inclusions are identified for all of the different shapes and sizes by the above guidelines, and the ratio of the oxides and (Nb, Ti)N is calculated. Further, this ratio is multiplied with the number of inclusions measured. If the carbides in the steel interfere with the above TEM observation, it is possible to use heat treatment to make the carbides agglomerate and grow or dissolve them to facilitate the observation of the composite inclusions covered.

[0034] Next, the method of production will be explained. The final rolling end temperature has to be made the Ar_3 transformation point or more so as to inhibit the formation of ferrite and improve the hole expansibility. However, if too high a temperature, the coarsening of the structure results in the reduction of the strength and a drop in the ductility, so the temperature is preferably made 950°C or less. The cooling speed has to be 20°C/s or more to suppress the formation of carbides harmful to hole expansibility and obtain a high hole expansion ratio. If the coiling temperature is less than 350°C, hard martensite harmful to the hole expansibility is formed, so the temperature is made 350°C or more. On the other hand, if the upper limit becomes over 600°C, pearlite and cementite harmful to the hole expansibility are formed, so the limit is made 600°C or

53

less.

[0035] The air cooling during continuous cooling is effective for increasing the ratio of the ferrite phase and improving the ductility. However, if pearlite is formed due to the air cooling temperature and the air cooling time, conversely the ductility falls and, not only that, the hole expansibility remarkably drops. If the air cooling temperature is less than 650°C, pearlite harmful to hole expansibility is formed early, so the temperature is made 650°C or more. On the other hand, if over 700°C, the ferrite formation is slow and the effect of air cooling is difficult to obtain and, not only that, pearlite is more easily formed during the subsequent cooling, so the temperature is made 700°C or less. If air cooling for over 15 seconds, not only is the increase of the ferrite phase saturated, but also a load is placed on control of the cooling speed and coiling temperature. For this reason, the air cooling time is made 15 seconds or less.

[0036] Next, the order of addition of ingredients at the stage of adjustment in the production process was studied by the inventors. As a result, when adding Si and Mn, then adding Ti, then adding Mg and Al, the yield of Mg in the molten steel increases and the oxides become finer in size and therefore the state of dispersion of the size of oxides demanded in the present invention becomes easier to stably obtain, so this is more preferable.

[0037] Mg has a high volatility in molten steel. If charging it into molten steel in the form of Mg pure metal, the yield of Mg is extremely low. For this reason, Mg is charged into the molten steel in the form of an alloy with a dilute solvent metal. At this time, the inventors engaged

54

in in-depth studies and as a result discovered that when using an Mg alloy comprised of one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as a dilute solvent metal of Mg, the amount of Mg remaining in the steel is improved. With an alloy mainly comprised of another metal, this effect could not be obtained. As the dilute solvent metal of Mg, it is preferable to select Si, Ni, Cu, Al, or an REM (rare earth metal) having interaction of interatomic forces with Mg. Among these, it is preferable to use an Mg alloy comprising one or more of these to charge Mg in the molten steel. Here, the range of the "rare earth metals", as, for example, described in the Physiochemical Dictionary, Edition 5, page 309, Iwanami Shoten, 1998, is the general name for the Sc, Y, and lanthanoids (La of atomic number 57 to Lu of 71) belonging to Group III of the Periodic Table.

[0038] Further, the inventors engaged in in-depth studies and as a result discovered that if the concentration of Mg in the Mg alloy is less than 10%, the Mg yield remarkable increases and a suitable size and number of oxides are easily stably obtained. On the other hand, if less than 1%, at the time of addition of Mg alloy, the dilute solvent metal excessively dissolves in the steel, so adjustment of the ingredients becomes difficult. Therefore, the concentration of Mg in the alloy is preferably made 1% to less than 10%.

[0039] The inventors discovered that when the sum of the concentrations of the Fe, Mn, and Cr in the Mg alloy is less than 10%, the Mg yield remarkably increases and further a suitable size and number of oxides are easily stably obtained. This is interpreted as being due to the action of interatomic repulsion between the Mg formed when

the Mg alloy dissolves in the molten steel and these elements. Therefore, the sum of the concentrations of the Fe, Mn, and Cr in the Mg alloy is preferably less than 10%. Even if the steel sheet of the present invention is hot rolled, then plated by annealing as with hot dip galvanization, the effect of the present invention will not be impaired. Further, even if hot rolled, then electroplated and given an organic composite film, the effect will not be impaired.

[0040]

[EXAMPLES] Next, the present invention will be explained based on examples. To produce steel of the steel ingredients shown in Table 1, pig iron 270t was decarburized by a converter to the target C concentration, then the molten steel was transferred to a ladle and deoxidized and adjusted in alloy by the CAS method (described in the Iron and Steel Institute of Japan ed., Hiroyuki Kajioka, Ladle Refining Method, page 104, Chijinshokan, issued in 1997). Examples of deoxidizing the molten steel by adding Si and Mn, then adding Ti, then adding Mg and Al in that order and other examples are shown in Table 1. Here, as the Si, Mn, and Ti material, FeSi, FeMn, and FeTi was used. Further, examples of using Mg alloys using one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as the dilute solvent metal for Mg and Al, having a concentration of Mg in the Mg alloy of 1% to less than 10%, and having concentrations of Fe, Mn, and Cr in the Mg alloy of less than 10% and examples of using other alloys are also shown in Table 1. After deoxidation, the necessary elements were adjusted to target ranges of the concentrations of ingredients, then immediately a

continuous casting machine was used to produce slabs of a thickness of 250 mm and a width of 1300 mm. These steels were heated to 1200°C or more in a heating furnace and rolled and cooled under the hot rolling conditions shown in Table 2 to obtain hot rolled steel sheets of a thickness of 2.6 to 3.2 mm.

[0041] On the other hand, Table 3 shows examples of use of an Mg alloy using one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as a dilute solvent metal for addition of Mg, having a concentration of Mg in the Mg alloy of 1% to less than 10%, and having a sum of concentrations of Fe, Mn, and Cr in the Mg alloy of less than 10% and, at the stage of adjusting the ingredients in the process of production, adding Si and Mn, then adding Ti, then adding Mg and Al for deoxidation. It shows the changes in ingredients. The notations D to Y show steels in accordance with the present invention, while the other notations show steels with amounts of addition of C, Si, Mn, S, Al, Mg, Nb, or Ti outside the scope of the present invention. These steels were heated to 1200°C or more in a heating furnace and hot rolled and cooled under the hot rolling conditions shown in Table 4 to obtain hot rolled steel sheets of a thickness of 2.6 to 3.2 mm.

[0042] Further, extraction replica samples were prepared from the steel sheet base materials and measured by the above-mentioned methods for the size and numbers of oxides and (Ti, Nb)N composite oxides using these as nuclei which were then converted to a number of per unit. This is shown in Tables 1 and 3.

[0043] JIS No. 5 pieces of the hot rolled steel sheet obtained in this way were subjected to tensile tests and

hole expansion tests and observed for structure. The hole expansibility (λ) was evaluated by pushing wider a diameter 12 mm punched hole by a 60° conical punch and determining $\lambda=(d-d0)/d0\times100$ from the hole diameter (d) at the time when the crack passed through the sheet thickness and the initial hole diameter (d0: 12 mm).

[0044] The TS, El, and λ of the test pieces are shown in Tables 2 and 4. <u>FIG. 1</u> shows the relationship between the strength and elongation, while <u>FIG. 2</u> shows the relationship between the strength and hole expansion ratio. It is learned that the invention steels have a hole expansion ratio higher than Comparative Steel 1 and both a hole expansion ratio and elongation higher than Comparative Steel 2. In this way, it is learned that the steel sheets of the present invention are excellent in both the hole expansion ratio and ductility.

[0045] Note that here the alloy was charged by the CAS method, but the invention is not particularly limited to this. We add that the vacuum tank alloy addition method of an RH degassing apparatus, molten steel ladle wire addition method, powder injection method, or other known method may also be used without problem.

[0046]

58

[Table 1]

Steel	C	Si	Mn	P	S	N	Mg	Al	Nb	Ti	Ca	Order of addition	Dilute solvent metal	Mg conc. %	Fe, Mn, Cr conc. %	No. of precipitates /mm2	Ar3 °C	Remarks
A1	0.041	0.50	1.50	0.010	0.003	0.002	0.0047	0.005	0.030	0.071	–	Si–Mn–Ti–Mg–Al	S,Si	7	8	4.0E+03	798	Inv. ex
A2	0.040	0.50	1.51	0.010	0.003	0.002	0.0047	0.002	0.031	0.071	–	Si–Mn–Ti–Mg–Al	Ni	8	4	3.5E+03	795	Inv. ex
A3	0.038	0.49	1.50	0.011	0.002	0.003	0.0047	0.005	0.030	0.070	–	Si–Mn–Ti–Mg–Al	Cu,Al	5	7	3.8E+03	797	Inv. ex
A4	0.040	0.49	1.50	0.010	0.003	0.002	0.0000	0.005	0.031	0.071	–	Si–Mn–Ti–Mg–Al	Ni	8	15	4.0E+02	798	Comp.ex
A5	0.040	0.48	1.50	0.010	0.004	0.002	0.0004	0.004	0.031	0.071	–	Si–Mn–Ti–Mg–Al	Si	13	5	9.0E+02	795	Comp.ex
A6	0.040	0.51	1.50	0.010	0.003	0.003	0.0003	0.005	0.028	0.071	–	Si–Mn–Ti Mg Al	Fe	5	80	5.0E+02	798	Comp.ex
A7	0.041	0.50	1.51	0.011	0.002	0.002	0.0035	0.005	0.028	0.073	–	Mg–Al–Si–Mn–Ti	Si	7	8	6.0E+02	795	Comp.ex
B1	0.029	0.70	1.30	0.016	0.003	0.002	0.0025	0.033	0.020	0.000	0.003	Si–Mn–Ti–Mg–Al	Si	7	8	2.5E+04	788	Inv. ex
B2	0.028	0.69	1.32	0.016	0.002	0.002	0.0024	0.033	0.020	0.000	0.003	Si–Mn–Ti–Mg–Al	Ni	8	4	2.4E+04	782	Inv. ex
B3	0.028	0.70	1.32	0.016	0.002	0.003	0.0020	0.035	0.020	0.000	0.003	Si–Mn–Ti–Mg–Al	Si,Ni	7	8	2.2E+04	782	Inv. ex
B4	0.029	0.70	1.30	0.016	0.003	0.002	0.0030	0.034	0.020	0.000	0.002	Si Mn–Ti–Mg–Al	Cu,Ni	5	7	2.4C104	783	Inv. ex
B5	0.028	0.70	1.30	0.016	0.002	0.002	0.0020	0.034	0.020	0.000	0.002	Si–Mn–Ti–Mg–Al	Al	8	9	2.2E+04	783	Inv. ex
B6	0.029	0.70	1.31	0.016	0.002	0.003	0.0028	0.035	0.020	0.000	0.002	Si–Mn–Ti–Mg–Al	REM,Si	9	9	2.1E+04	782	Inv. ex
B7	0.029	0.69	1.31	0.016	0.002	0.002	0.0004	0.036	0.020	0.000	0.000	Si–Mn–Ti–Mg–Al	Si	13	5	6.0C 102	702	Comp.ex
B8	0.028	0.69	1.30	0.016	0.003	0.003	0.0000	0.036	0.020	0.000	0.000	Si–Mn–Ti–Mg–Al	Fe,Mn	8	80	2.0E+02	783	Comp.ex
B9	0.028	0.72	1.32	0.010	0.002	0.002	0.0002	0.033	0.020	0.000	0.003	Si–Mn–Ti–Mg–Al	Fe,Cr	1	70	4.0E+02	783	Comp.ex
B10	0.028	0.69	1.90	0.015	0.002	0.002	0.0020	0.033	0.020	0.000	0.003	Si–Mg–Mn–Ti–Al	Si	7	8	1.9E+02	782	Comp.ex
B11	0.029	0.71	1.91	0.015	0.002	0.002	0.0015	0.033	0.020	0.000	0.002	Mg–Al–Si Mn Ti	Al	6	8	2.0E+02	782	Comp.ex
C	0.035	0.69	2.01	0.012	0.003	0.002	0.0030	0.035	0.035	0.080	–	Si–Mn–Ti–Mg–Al	Si	7	8	2.0E+04	777	Inv. ex
C2	0.034	0.90	2.02	0.012	0.002	0.003	0.0029	0.035	0.033	0.080	0.002	Si–Mn–Ti–Mg–Al	Ni	8	4	1.9E+04	777	Inv. ex
C3	0.035	0.90	2.01	0.011	0.002	0.003	0.0032	0.033	0.035	0.081	0.007	Si–Mn–Ti–Mg–Al	REM,Si	9	9	1.8E+05	777	Inv. ex
C4	0.035	0.88	2.02	0.011	0.048	0.002	0.0032	0.034	0.035	0.080	0.003	Si–Mn–Ti Mg Al	S,Ni	7	8	2.2E+04	776	Inv. ex
C5	0.034	0.89	2.02	0.011	0.003	0.003	0.0032	0.034	0.035	0.080	0.002	Si–Mn–Ti–Mg–Al	Cu,Ni	5	7	2.0E+04	777	Inv. ex
C6	0.034	0.90	2.01	0.012	0.003	0.002	0.0031	0.035	0.035	0.081	0.002	Si–Mn–Ti–Mg–Al	REM,Ni	9	9	1.9E+04	778	Inv. ex
C7	0.035	0.89	2.01	0.012	0.003	0.003	0.0029	0.035	0.035	0.080	0.003	Si–Mn–Ti–Mg–Al	Ni	9	0	1.5E+02	777	Comp.ex
C8	0.033	0.90	2.00	0.012	0.002	0.003	0.0031	0.035	0.034	0.050	0.002	Mg–Al–S–Mn–Ti	Si	7	8	4.0E+02	779	Comp.ex

* Provided that Ar3=896−509(C%)+26.9(Si%A)−63.5(Mn%)+229(P%)

[0047]

[Table 2]

Steel	Final temp. °C	Cooling speed °C/s	Air cooling start temp. °C	Air cooling time s	Coiling temp. °C	Tensile strength N/mm2	Elongation	Hole expansion %	Remarks
A1	860	60	680	3	510	696	28	115	Inv. steel
A2	870	50	670	3	550	697	28	115	Inv. steel
A3	860	80	--	-	500	694	26	125	Inv. steel
A4	860	60	670	4	510	695	27	75	Comp. steel
A5	870	60	670	4	490	694	26	70	Comp. steel
A6	880	60	670	3	500	695	26	70	Comp. steel
A7	860	60		-	500	698	21	85	Comp. steel
B1	870	60	660	4	500	646	27	130	Inv. steel
B2	870	60	670	8	550	646	27	125	Inv. steel
B3	880	30	670	4	450	647	27	125	Inv. steel
B4	870	60	-	-	550	645	27	120	Inv. steel
B5	880	70	--	-	490	646	26	130	Inv. steel
B6	860	50	--	-	440	647	27	125	Inv. steel
B7	850	60	670	8	550	646	26	85	Comp. steel
B8	870	60	670	8	550	645	27	80	Comp. steel
B9	870	60	--	-	460	649	26	80	Comp. steel
B10	870	50	--	-	500	644	24	90	Comp. steel
B11	860	50	--	-	480	647	25	85	Comp. steel
C1	860	50	680	4	550	782	24	105	Inv. steel
C2	860	50	670	8	500	782	25	100	Inv. steel
C3	880	60	670	3	550	781	25	105	Inv. steel
C4	880	40	-	-	450	782	23	105	Inv. steel
C5	870	50	-	-	500	782	23	100	Inv. steel
C6	870	50	680	4	540	783	25	110	Inv. steel
C7	860	50	670	4	550	782	22	65	Comp. steel
C8	870	60	680	4	550	781	19	60	Comp. steel

Asterisked conditions in table are outside scope of present invention

[0048]

[Table 3]

Steel	C	Si	Mn	P	S	N	Mg	Al	Nb	Ti	Ca	REM	No. of prec./mm²	Ar3 °C	Remarks
	wt%														
D	0.03	0.3	2.0	0.010	0.003	0.002	0.0022	0.031	0.015	—	—	—	1.5E+04	764	Inv. ex.
E	0.01	0.9	1.1	0.013	0.003	0.002	0.0033	0.030	0.035	—	0.0025	—	1.2E+04	848	Inv. ex.
F	0.04	1.1	1.6	0.025	0.003	0.002	0.0037	0.005	0.040	0.130	0.0020	—	1.0E+04	809	Inv. ex.
G	0.03	0.9	1.4	0.010	0.002	0.003	0.0034	0.002	0.030	—	—	—	1.5E+04	818	Inv. ex.
H	0.03	1.5	2.5	0.015	0.003	0.002	0.0100	0.045	—	0.120	0.0030	—	1.0E+07	765	Inv. ex.
I	0.04	0.5	1.5	0.010	0.003	0.002	0.0011	0.005	0.030	0.070	0.0030	—	4.0E+03	796	Inv. ex.
J	0.04	0.5	1.5	0.010	0.003	0.002	0.0047	0.005	0.030	0.070	0.0030	—	8.0E+03	796	Inv. ex.
K	0.04	0.9	2.0	0.012	0.002	0.005	0.0047	0.005	0.040	0.070	0.0030	—	8.0E+03	775	Inv. ex.
L	0.04	0.9	2.0	0.012	0.002	0.003	0.0025	0.035	0.025	—	0.0030	—	1.0E+04	775	Inv. ex.
M	0.04	1.5	0.5	0.030	0.002	0.002	0.0025	0.033	0.025	—	0.0025	—	2.0E+04	891	Inv. ex.
N	0.05	0.5	2.0	0.018	0.003	0.003	0.0032	0.034	0.030	0.080	—	—	2.2E+34	772	Inv. ex.
O	0.06	0.8	2.0	0.012	0.002	0.003	0.0031	0.005	0.035	0.120	0.0020	—	2.0E+03	763	Inv. ex.
P	0.08	0.8	1.0	0.015	0.003	0.002	0.0030	0.005	0.030	—	—	—	7.0E+03	827	Inv. ex.
Q	0.05	1.4	1.5	0.012	0.002	0.003	0.0025	0.035	0.035	0.090	—	—	3.0E+04	815	Inv. ex.
R	0.05	1.3	2.0	0.011	0.003	0.002	0.0016	0.030	—	0.150	0.0020	—	4.0E+04	781	Inv. ex.
S	0.07	0.4	2.0	0.016	0.003	0.002	0.0022	0.005	0.020	—	0.0020	—	3.0E+03	748	Inv. ex.
T	0.07	1.3	1.6	0.014	0.007	0.002	0.0033	0.005	0.030	0.080	0.0020	—	1.0E+04	797	Inv. ex.
U	0.10	1.3	1.4	0.010	0.004	0.002	0.0029	0.030	—	0.010	0.0020	—	3.0E+04	793	Inv. ex.
V	0.05	1.3	2.0	0.015	0.003	0.002	0.0031	0.005	0.035	0.210	0.0020	—	5.0E+04	782	Inv. ex.
W	0.13	1.0	2.2	0.020	0.003	0.002	0.0040	0.030	0.035	0.155	—	—	1.5E+04	721	Inv. ex.
X	0.08	1.3	1.5	0.020	0.003	0.002	0.0032	0.035	0.035	0.250	0.0020	—	3.0E+04	810	Inv. ex.
Y	0.10	1.3	1.4	0.010	0.004	0.002	0.0029	0.030	0.000	0.010	—	0.0020	3.0E+04	783	Inv. ex.
Z	0.05	0.1	1.8	0.016	0.003	0.002	0.0022	0.035	0.035	—	0.0020	—	3.0E+04	756	Comp. ex.
a	0.04	0.9	2.7	0.014	0.003	0.002	0.0033	0.035	0.020	0.080	0.0020	—	3.0E+04	731	Comp. ex.
b	0.05	0.4	1.8	0.010	0.012	0.002	0.0029	0.005	—	0.010	0.0020	—	3.0E+03	763	Comp. ex.
c	0.10	0.6	1.5	0.015	0.003	0.002	0.0016	0.005	0.035	0.120	0.0020	—	1.0E+03	769	Comp. ex.
d	0.04	0.6	1.9	0.012	0.003	0.003	0.0110	0.034	0.015	—	—	—	8.0E+03	774	Comp. ex.
e	0.06	1.2	2.1	0.017	0.003	0.003	0.0020	0.080	0.030	0.080	0.0020	—	4.0E+03	768	Comp. ex.
f	0.06	0.8	1.0	0.017	0.003	0.002	0.0032	—	0.030	—	0.0020	—	8.0E+03	827	Comp. ex.
g	0.05	0.9	1.9	0.016	0.003	0.002	0.0030	0.033	—	—	—	—	8.0E+03	778	Comp. ex.

*Provided, that $Ar_3 = 896 - 50\%(C\%) + 26.9(Si\%) - 63.5(Mn\%) + 229(P\%)$

[0049]

[Table 4]

Steel	Temp. °C	Temp. °C/s	Air cooling start temp. °C	Air cooling time s	Coiling temp. °C	Tensile strength N/mm2	Elongation %	Hole expansion %	Remarks
D1	840	60	670	4	450	584	31	130	Inv. steel
D2	870	60	—	—	550	594	29	135	Inv. steel
E1	870	50	670	4	480	590	31	125	Inv. steel
E2	870	60	—	—	550	595	30	135	Inv. steel
F1	880	60	670	3	580	709	24	95	Inv. steel
F2	870	60	—	—	550	794	23	100	Inv. steel
F3	850	10	870	4	480	779	20	70	Comp. steel
G1	880	60	670	3	450	601	30	125	Inv. steel
G2	870	60	—	—	550	606	29	130	Inv. steel
H1	890	60	680	3	460	819	22	100	Inv. steel
H2	870	60	—	—	550	829	21	105	Inv. steel
I1	860	60	680	3	510	680	27	110	Inv. steel
I2	870	60	—	—	550	690	25	115	Inv. steel
J1	870	50	670	3	490	684	26	110	Inv. steel
J2	870	60	—	—	550	692	25	115	Inv. steel
K1	860	60	680	3	500	780	24	95	Inv. steel
K2	870	30	680	4	550	778	25	100	Inv. steel
K3	850	50	680	5	300	788	24	50	Comp. steel
K4	900	30	660	3	640	785	22	65	Comp. steel
K5	870	70	630	6	490	790	21	65	Comp. steel
K6	580	50	720	6	550	780	20	75	Comp. steel
K7	580	10	680	3	500	765	19	75	Comp. steel
K8	870	60	—	—	550	787	22	100	Inv. steel
K9	880	10	—	—	480	767	21	70	Comp. steel
L1	880	60	670	4	510	687	28	120	Inv. steel
L2	870	60	—	—	550	682	27	125	Inv. steel
M1	870	60	670	4	490	614	31	125	Inv. steel
M2	870	60	—	—	550	624	28	130	Inv. steel
N1	880	60	670	3	500	781	23	105	Inv. steel
N2	850	50	680	5	300	791	24	55	Comp. steel
N3	880	50	720	6	550	779	20	65	Comp. steel
N4	870	60	—	—	550	794	23	110	Inv. steel
N5	880	10	—	—	480	772	19	70	Comp. steel
O1	860	60	670	3	500	784	24	95	Inv. steel
O2	870	60	—	—	550	796	24	100	Inv. steel
P1	860	60	680	3	510	596	30	125	Inv. steel
P2	870	60	—	—	550	604	29	130	Inv. steel
Q1	870	50	670	3	490	785	24	105	Inv. steel
Q2	870	60	—	—	550	795	23	110	Inv. steel
R1	860	60	680	3	500	796	25	100	Inv. steel
R2	870	60	—	—	550	807	22	110	Inv. steel
R3	880	40	—	—	700	792	22	70	Comp. steel
S1	860	60	670	4	510	609	30	125	Inv. steel
S2	870	60	—	—	550	619	29	125	Inv. steel
T1	860	60	680	3	480	787	23	90	Inv. steel
T2	870	60	—	—	550	798	22	90	Inv. steel
U1	870	50	670	3	500	684	28	120	Inv. steel
U2	870	60	—	—	550	694	26	125	Inv. steel
V1	860	60	680	4	490	1043	17	55	Inv. steel
V2	860	60	—	—	550	1038	16	65	Inv. steel
W1	870	60	670	4	500	996	18	65	Inv. steel
W2	870	60	—	—	550	1001	17	70	Inv. steel
X1	870	60	680	4	490	988	18	65	Inv. steel
X2	870	60	—	—	550	994	18	70	Inv. steel
Y1	870	60	680	4	500	683	27	120	Inv. steel
Y2	870	60	—	—	550	693	26	125	Inv. steel
Z	870	60	—	—	450	602	24	80	Comp. steel
a	860	70	660	5	510	800	17	60	Comp. steel
b	850	40	660	5	490	599	25	70	Comp. steel
c	880	70	—	—	590	780	19	65	Comp. steel

62

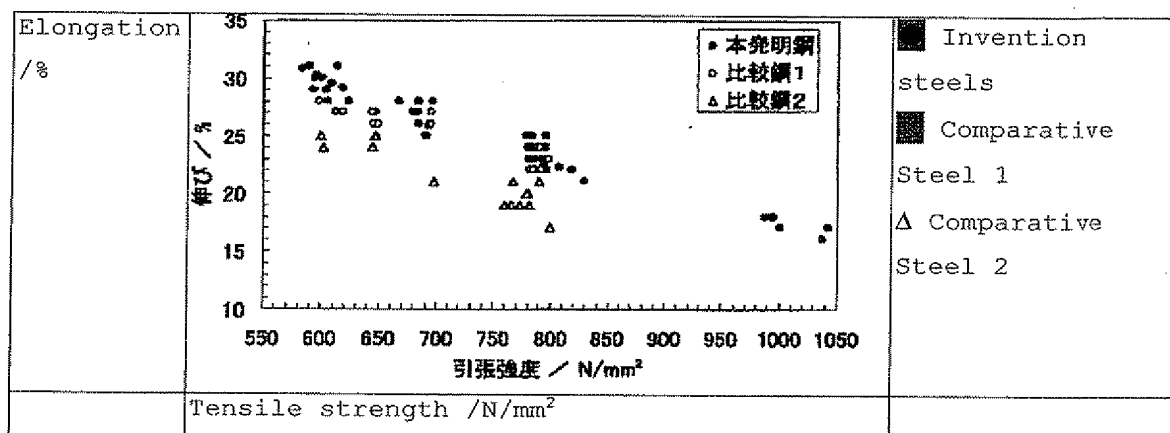|								
d	870	80	—	—	480	612	27	75	Comp. steel
e	880	40	680	4	480	798	23	55	Comp. steel
f	850	50	870	3	490	598	28	80	Comp. steel
g	880	50	—	—	490	819	27	70	Comp. steel

[0050]

[EFFECTS OF THE INVENTION] According to the present invention, it becomes possible to supply hot rolled high strength steel sheet having a strength level of the $590N/mm^2$ class or more and having an unprecedented elongation-ductility balance, so this is extremely useful in industry.
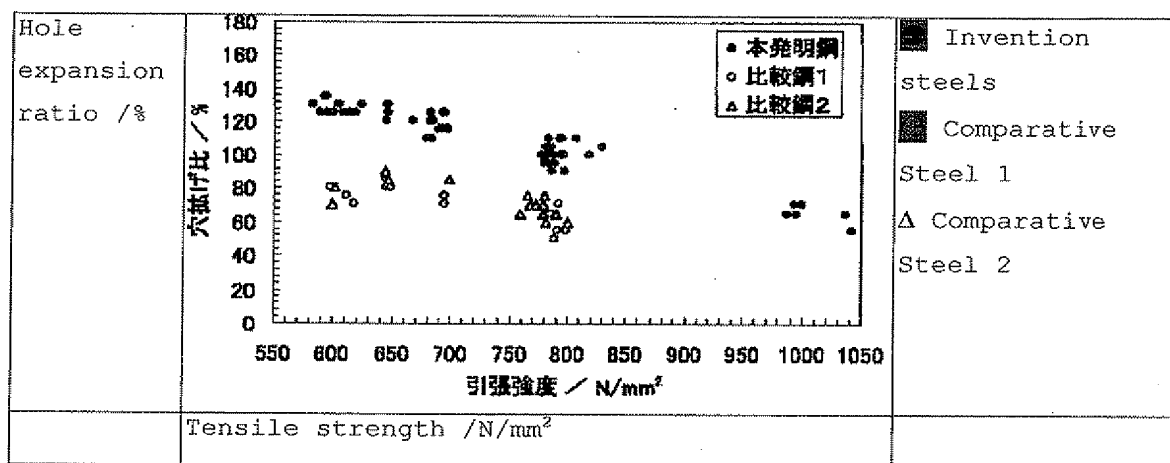
[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] a graph showing the relationship between the tensile strength and elongation.

[FIG. 2] a graph showing the relationship between the tensile strength and hole expansion ratio.

[FIG. 1]

Elongation /%		■ Invention steels ▨ Comparative Steel 1 △ Comparative Steel 2
	Tensile strength /N/mm²	

[FIG. 2]

Hole expansion ratio /%		■ Invention steels ▨ Comparative Steel 1 △ Comparative Steel 2
	Tensile strength /N/mm²	

[VOLUNTARY AMENDMENT]

[DATE OF SUBMISSION] January 12, 2001

[VOLUNTARY AMENDMENT 1]

[NAME OF DOCUMENT COVERED BY AMENDMENT] Specification

[NAME OF PARAGRAPH COVERED BY AMENDMENT] 0048

[METHOD OF AMENDMENT] Change

[CONTENT OF AMENDMENT]

[0048]

[Table 3]

Change steel "c", "0.10" to "0.21".